TF Logo: Flip Tanedo

Science Highlights

THEORY FRONTIER

COMMUNITY PLANNING 2021

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Csaba Csaki (Cornell)
Aida El-Khadra (UIUC)

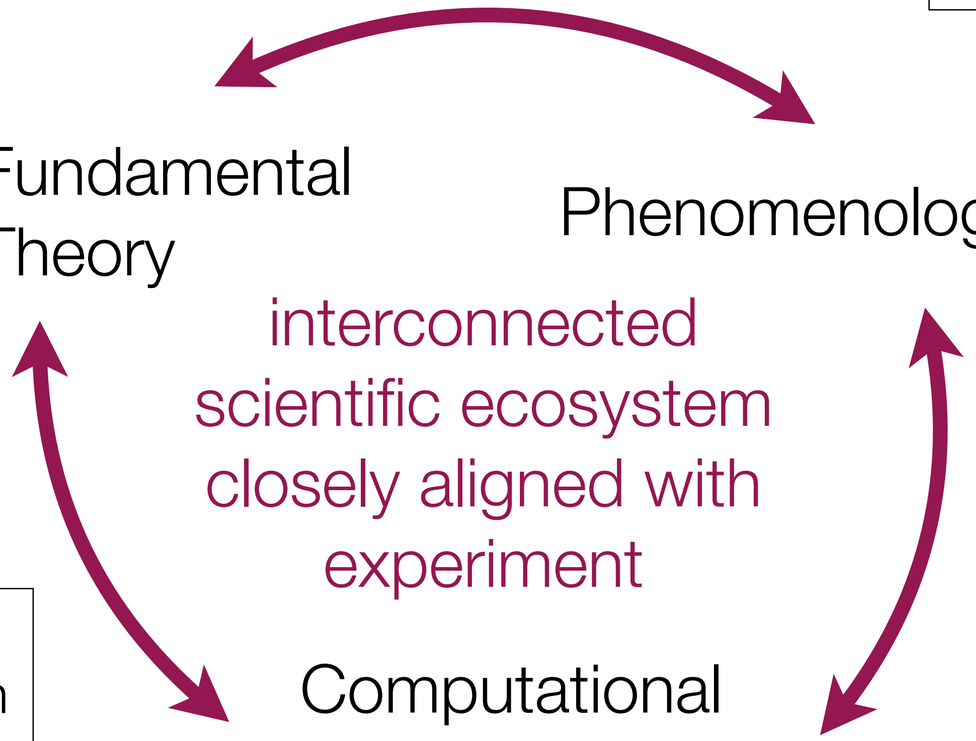
captions go here

HEP Theory

unifies the frontiers of particle physics

lays the foundations for future experiments

connects to gravity, cosmology, astrophysics nuclear physics, condensed matter, AMO, computer science, statistics, data science, mathematics



central to the motivation, analysis, and interpretation of experiments

advances our understanding of Nature in regimes that experiment cannot (yet) reach

responsive:
propose new directions based on data
propose/guide new experiments
develop new analysis tools

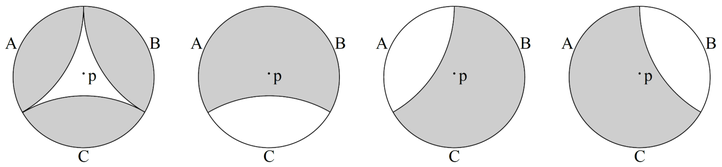
incorporates new perspectives (QI, ML) and computational technologies to extend the boundaries of our knowledge

Fundamental Theory

TF01

Holography (AdS/CFT) + QI (entanglement entropy)

➠ Quantum Error Correction

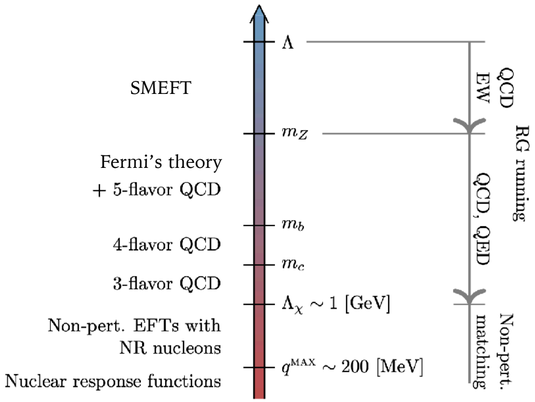


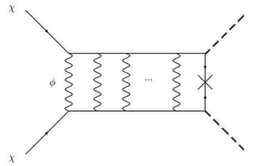
➠ black hole information paradox

X. Dong

TF02

new EFTS for DM, GWs, CM; SMEFT ➠ new applications



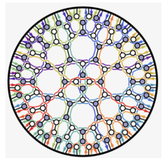


fundamental principles (symmetries, naturalness, unitarity, analyticity, causality,…)

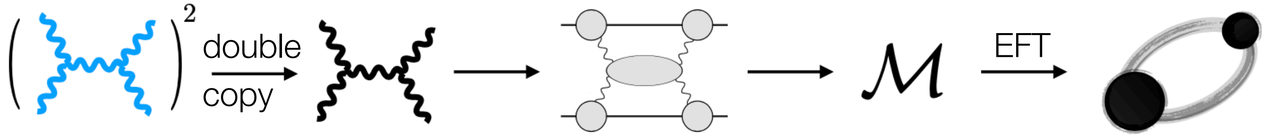
➠ new tools

P. Draper + K. Zhang

TF04



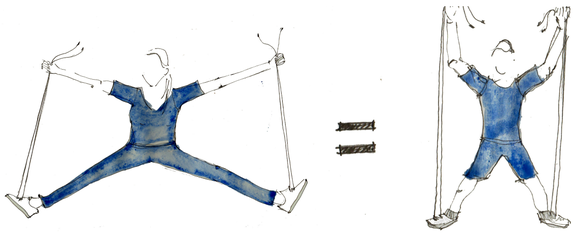
Leverage advanced QFT methods for state-of-the-art gravitational wave predictions



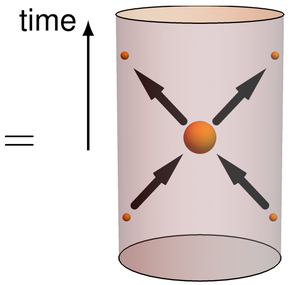
Z. Bern + E. Herrman + M. Solon

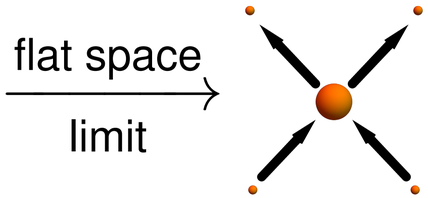
TF03

Bootstrap = the use of symmetry and other principles (unitarity/positivity, crossing) to constrain or determine a physical quantity.



CFT 4-pt fn =





bootstrapping quantum gravity

S. Pufu

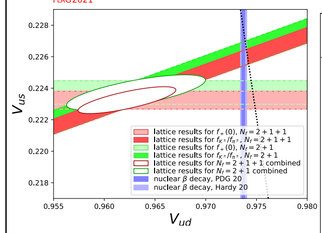
Phenomenology

TF05/06

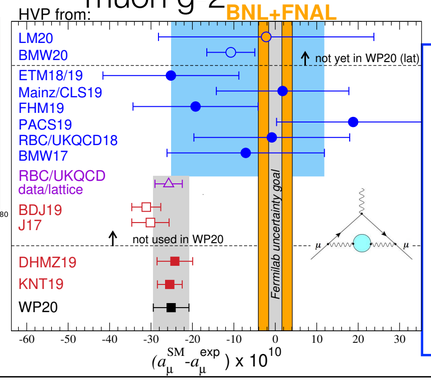
precision SM theory for flavor physics (EFT + loops + lattice QCD)

➠ **BSM constraints .. or discovery**

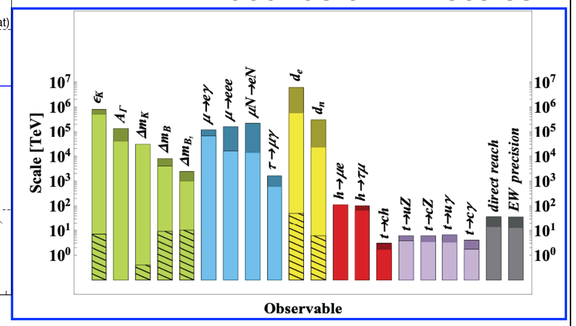
Cabbibo anomaly



muon g-2



bounds on NP scales



A. Kronfeld
O. Witzel
R. Boughezal

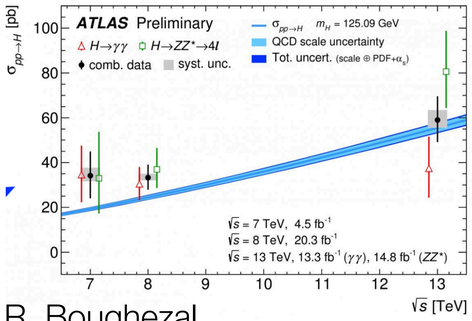
TF06

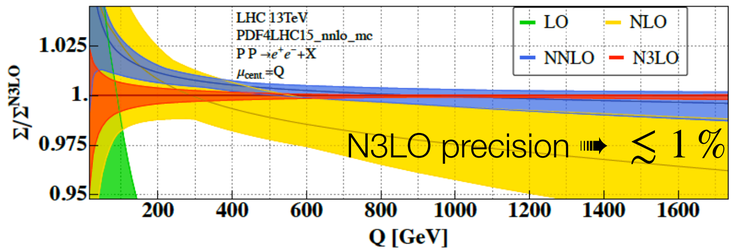
Precision Higgs: EW @ 2 loops

PDFs @ NNLO, pQCD @ N3LO $\delta\alpha_s < 1\,\%$

precision SM theory for collider physics (EFT + loops + PDFs+generators)

➠ **SM tests** $\lesssim 1\,\%$ **… or discovery**



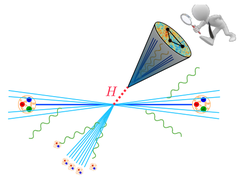


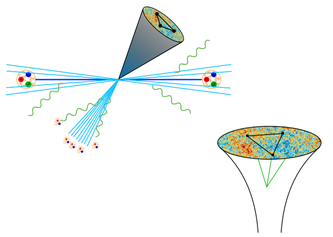
R. Boughezal

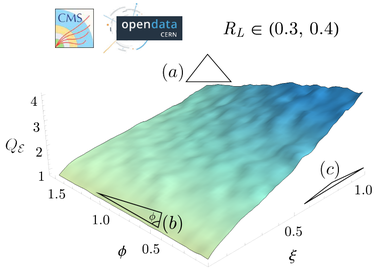
TF07

new observables, multi-point correlators leveraging ML/AI, computational theory, connections to fundamental theory

jet substructure







UV to IR ⟵ ⟶ Theory to Experiment

Technique from collider physics and QCD — Interpreted through lens of cosmology — Computed through lens of conformal field theory — Analyzed with public collider data

Phenomenological to Formal ⟵ ⟶

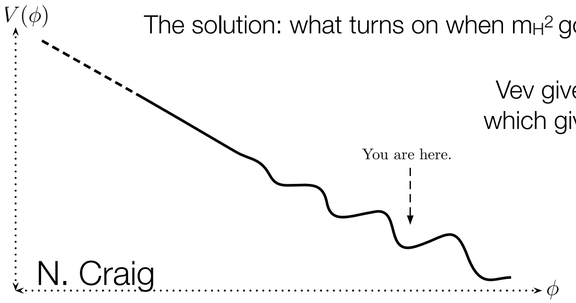
I. Moult + J. Thaler

TF08

new paradigms: hidden sectors, new symmetries, split spectra, neutral naturalness, …

➠ **new search strategies and constraints**

cosmic selection of EW vacuum



The solution: what turns on when m_H^2 goes negative?

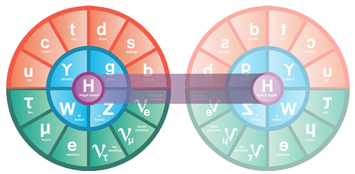
Vev gives quark masses which give axion potential.

"Relaxion"

[Graham, Kaplan, Rajendran '15]

N. Craig

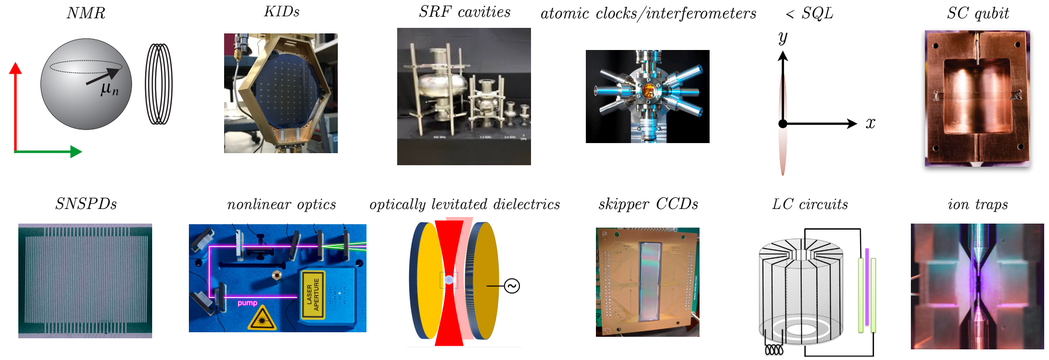
Twin Higgs



Phenomenology

TF09/10

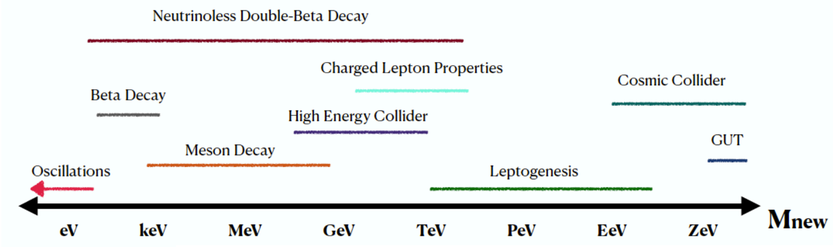
pursue new physics discoveries with new technologies for new experiments



A. Berlin

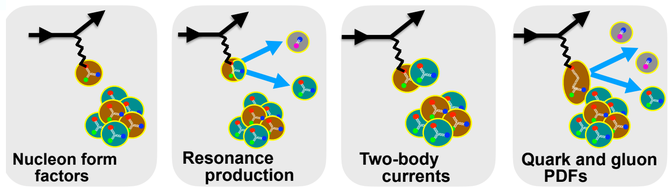
TF11

ν new mass scale: explore the space of BSM theories



ν cross sections across all energy scales in the SM and beyond:

broad program combining nuclear many body theory + EFT + lattice QCD + pQCD + generators

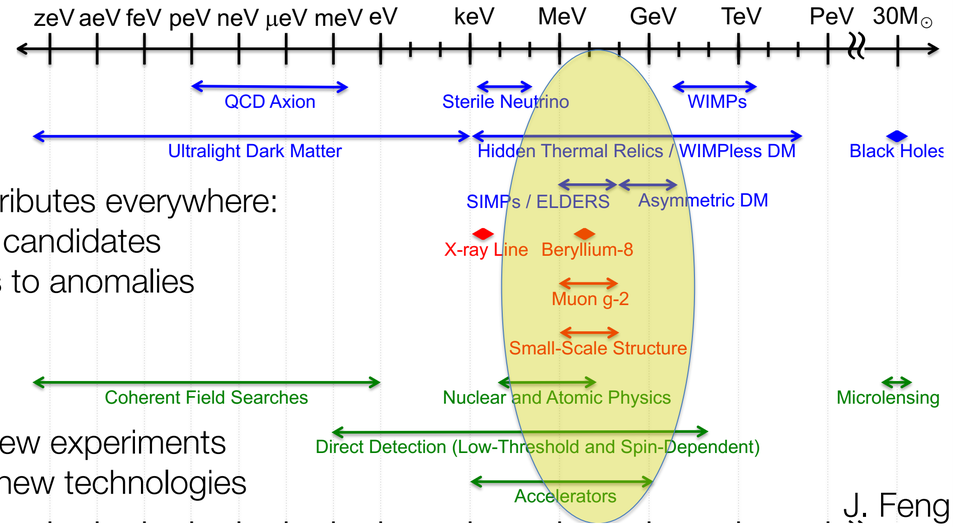


A. de Gouvêa+ M. Wagman

TF08/09

Dark Sector Candidates, Anomalies, and Search Techniques

DM



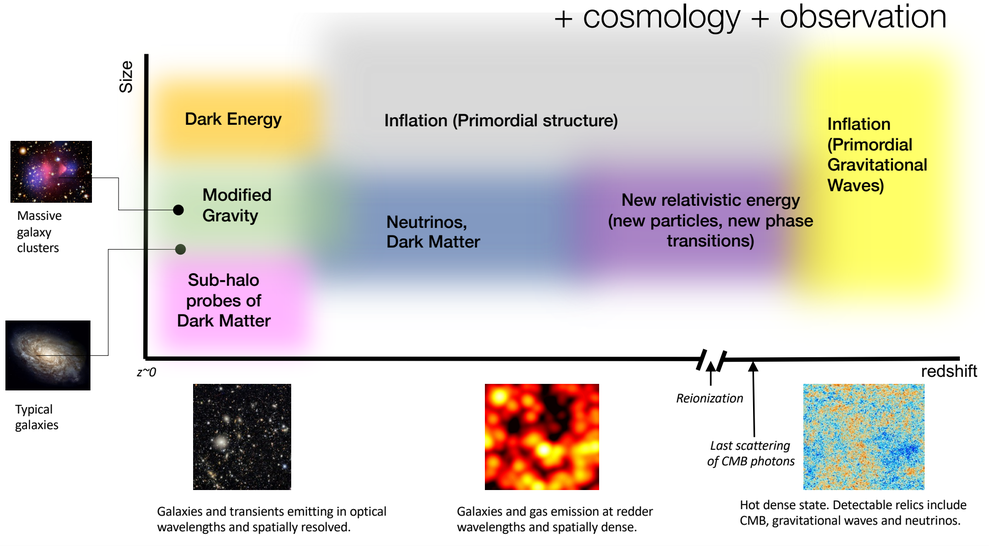
Theory contributes everywhere:
Dark sector candidates
connections to anomalies

proposing new experiments enabled by new technologies

J. Feng

TF09

Fundamental theory (bootstrap, EFT, …) + computational theory + cosmology + observation



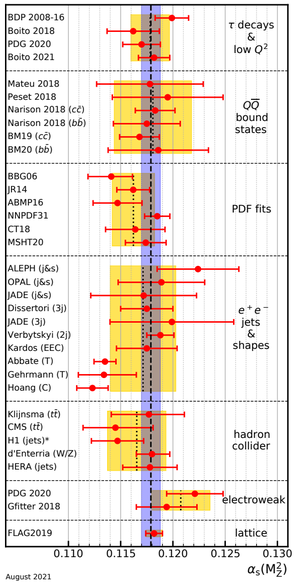
D. Green

Computational Theory

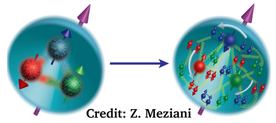
TF05

Lattice QCD: expanding the scope from precision to complexity

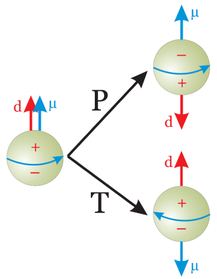
α_s



x-dependent PDFs

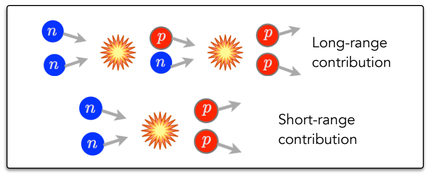


nucleon MEs (gA, nEDM,…)



multi-nucleon matrix elements

$$nn \to pp\, ee\, \overline{\nu}_e \overline{\nu}_e$$



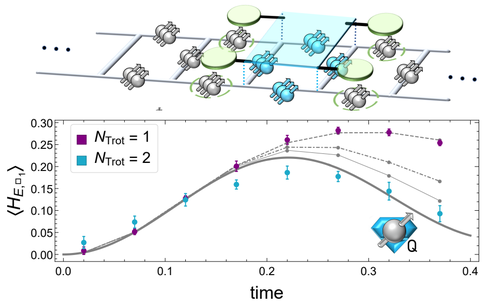
- Lattice calculations as a "numerical laboratory" push the boundaries of our knowledge of strongly-coupled physics - e.g. holography tests in N=4 SYM

Z. Davoudi + A. Kronfeld+
E. Neil + M. Wagman

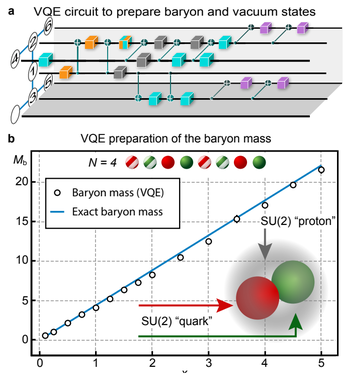
TF10

Quantum simulations on NISQ hardware: developing the infrastructure

Real-time dynamic of pure SU(2) with global irreps on IBM



Low-lying spectrum of SU(2) with matter in 1+1 D on IBM



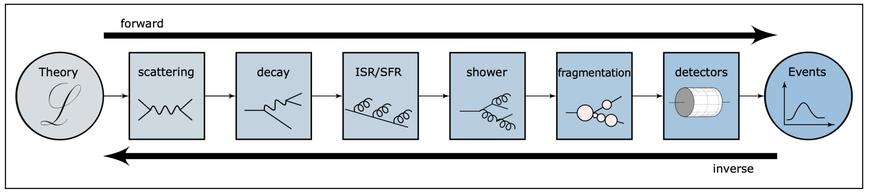
Tensor Networks

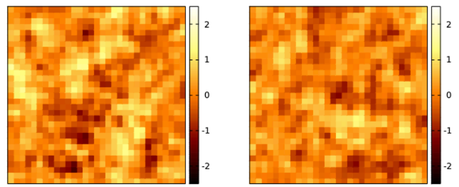
Discrete holography

S. Catterall + N. Klco + Z. Davoudi

ML/AI

The importance of ML for Collider Physics.





- development of new ML methods for gauge theory generation
- applications to observables

Z. Davoudi+C. Krause

Topical Group		Topical Group Conveners			
TF01	String theory, quantum gravity, black holes	Daniel Harlow	Shamit Kachru	Juan Maldacena	
TF02	Effective field theory techniques	Patrick Draper	Ira Rothstein		
TF03	CFT and formal QFT	David Poland	Leonardo Rastelli		
TF04	Scattering amplitudes	Zvi Bern	Jaroslav Trnka		
TF05	Lattice gauge theory	Zohreh Davoudi	Taku Izubuchi	Ethan Neil	
TF06	Theory techniques for precision physics	Radja Boughezal	Zoltan Ligeti		
TF07	Collider phenomenology	Fabio Maltoni	Shufang Su	Jesse Thaler	
TF08	BSM model building	Patrick Fox	Graham Kribs	Hitoshi Murayama	
TF09	Astro-particle physics and cosmology	Dan Green	Joshua Ruderman	Ben Safdi	Jessie Shelton
TF10	Quantum information science	Simon Catterall	Roni Harnik	Veronika Hubeny	
TF11	Theory of Neutrino Physics	André de Gouvêa	Irina Mocioiu	Saori Pastore	Louis Strigari

138 Snowmass White Papers submitted to TF!

Thank you!

Early Career
Rotating

Liaisons	**Accelerator** Lian-Tao Wang (U Chicago)	**Community Engagement** Devin Walker (Dartmouth)	**Computational** Steven Gottlieb (Indiana U)
Cosmic Flip Tanedo (UC Riverside)	**Energy** Laura Reina (Florida State U)	**Neutrino Physics** Irina Mociouiu (Penn State U) & Kaladi S. Babu (Oklahoma State U)	**Rare Processes and Precision** Alexey Petrov (Wayne State)